Development of the Horizon Plug-In Diesel Exhaust Purifier

Cleaire ICAT Project
Technical Seminar
August 31, 2006

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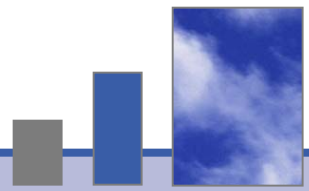
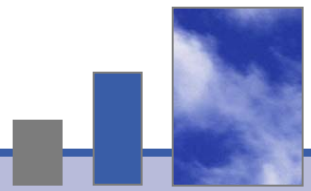
ADVANCED EMISSION CONTROLS®

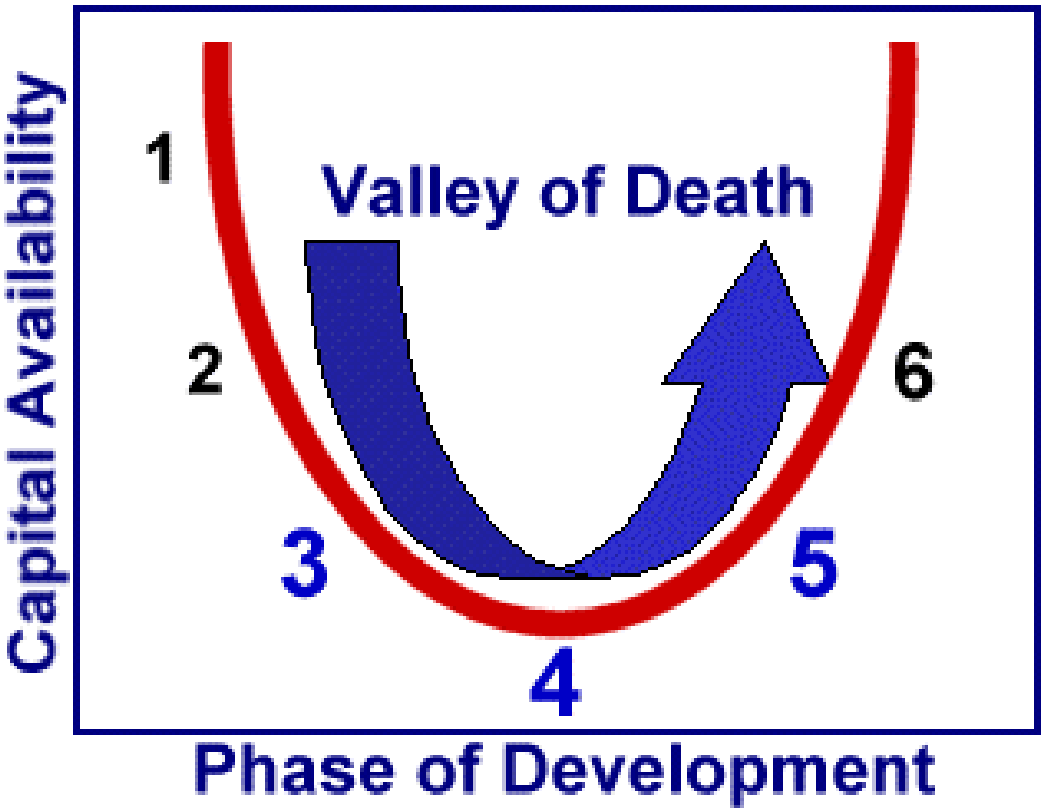


Seminar Agenda

- ICAT Project Overview
- Horizon (EPF) Product Overview
- ICAT Project Results
  - Test Results
  - Elk Grove School Bus Demonstration
  - Lessons Learned
- Horizon Commercialization
- ICAT Project Q&A (ARB and Cleaire)



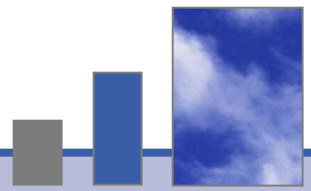
What ICAT Funds



1. Idea Development
2. Proof of Concept
3. Pilot
4. Prototype
5. Demonstration
6. Commercial sales

Cleaire ICAT Project Overview

- Demonstrate Horizon (EPF) in real-world use
  - Installation processes and operational robustness
  - Customer following procedures
  - Infrastructure installation, use and safety
- Test regeneration emissions
- Test PM control performance
- Learn from ICAT demonstration experience
  - Customer behavior
  - Identify unforeseen issues
- Follow ICAT project with
  - Verification and wide-spread deployment



Horizon (EPF) ICAT Project Tasks

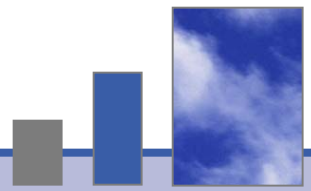
#	Task
1	Build prototype and test regeneration emissions. (3 months)
2	Install power-supply station (regenerative infrastructure). (3 months)
3	Install EPF (Horizon) on demonstration vehicles. (2 weeks)
4	Field testing of technology. (6 months)
5	Dynamometer emissions testing, final report and technical seminar. (2 weeks)

Motivation for Product

Level 3 PM control without NO_2 increase

Specifically for:

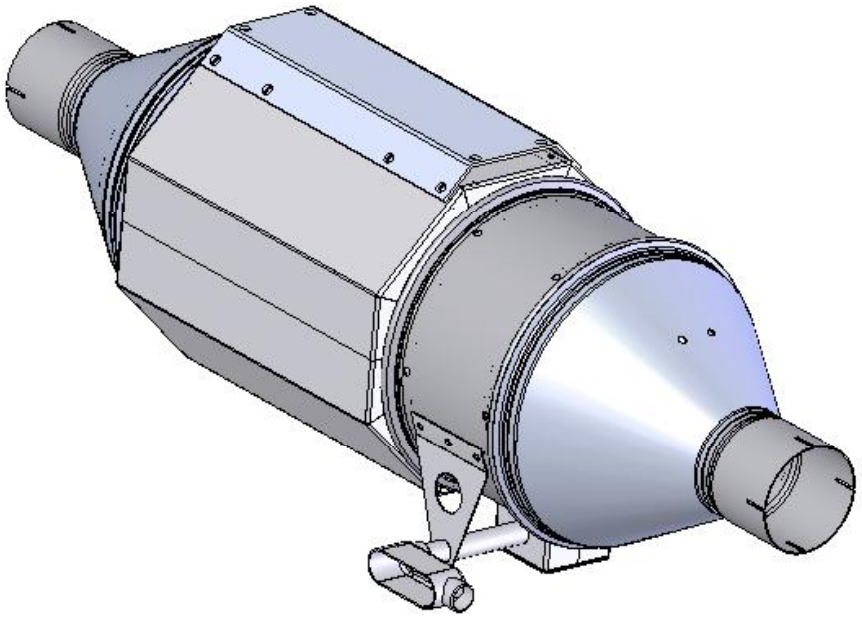
- Construction equipment
- Port equipment
- School buses
- Older engines
- Cold duty cycles



Technology options

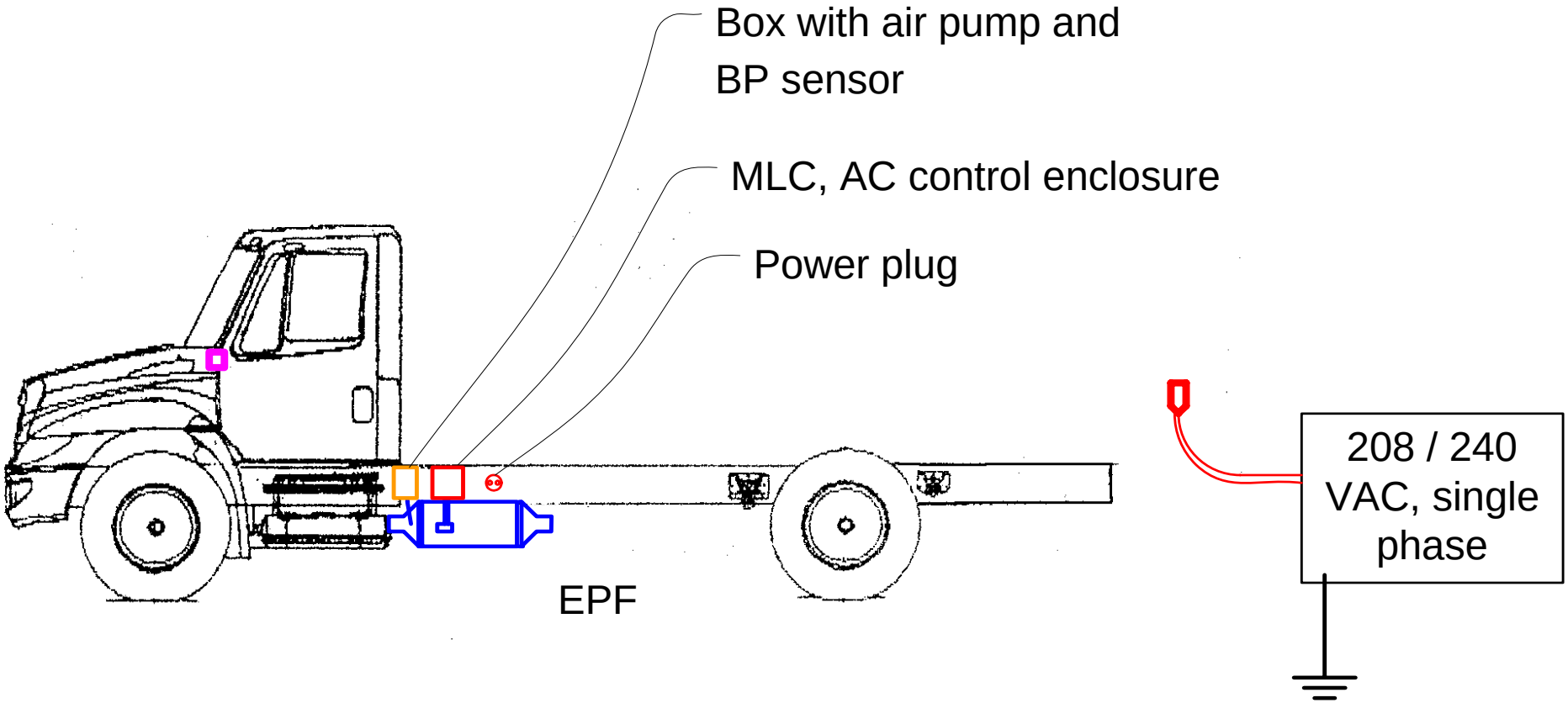
	PM mass	Particle count	NO2 increase	Temperature requirement
DOC	~25%	none	high	yes
Partial Filter	~50 %	some	high	yes
Catalyzed DPF	> 85%	>98%	high	yes
Active DPF (no catalyst)	> 85%	>98%	none	none

Horizon (EPF) Product Overview

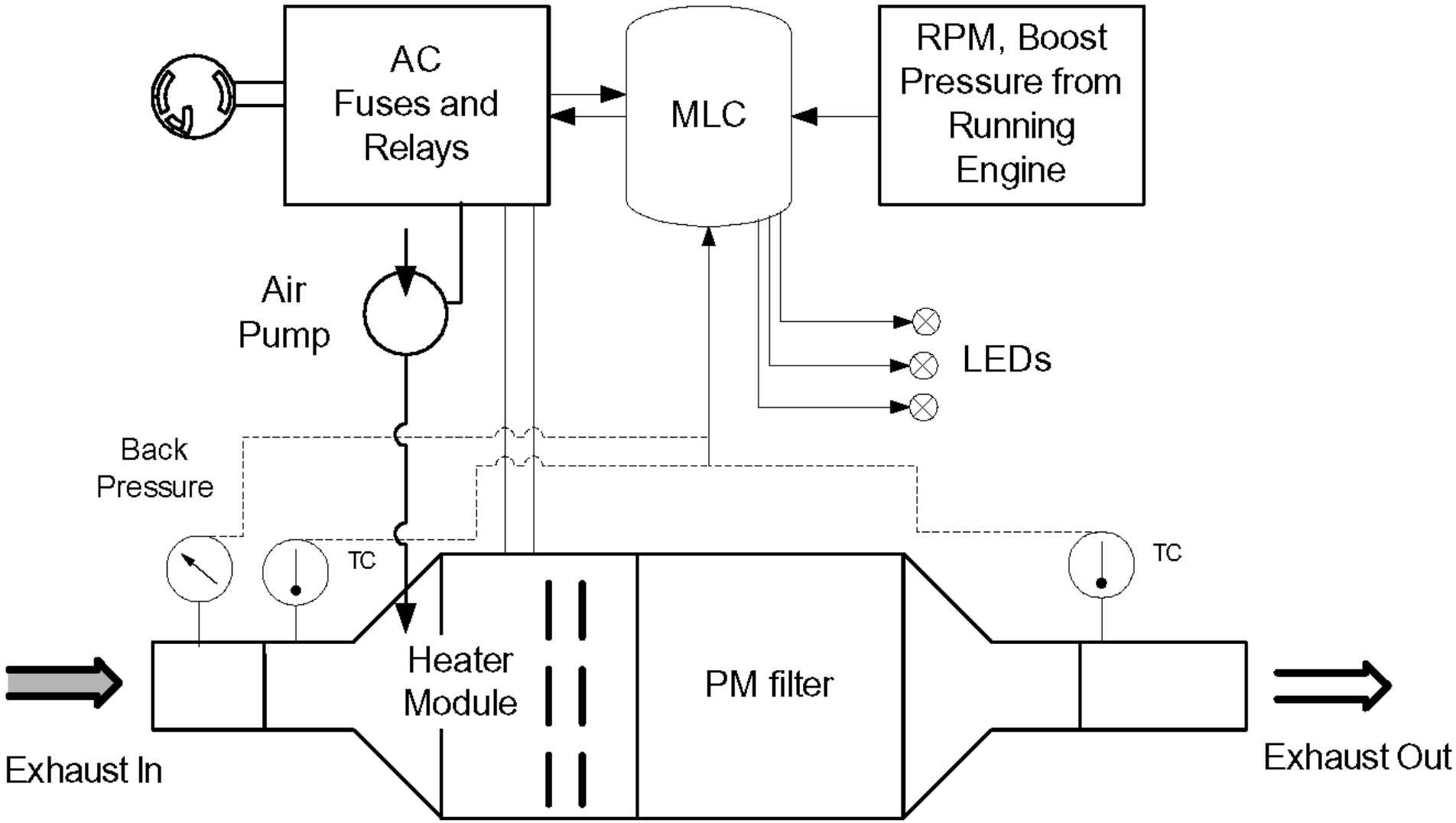


- Level 3+ PM control
- All duty-cycles
- Integrated system
  - Silicon Carbide PM filter (uncatalyzed)
  - Electric regeneration
  - Cleaire MLC® controls
- Engine on – passive
- Engine off – active
- Annual cleaning (de ash)

On- and Off-Vehicle Components



Horizon EPF System Schematic



PM Filter Assembly

PM Filter

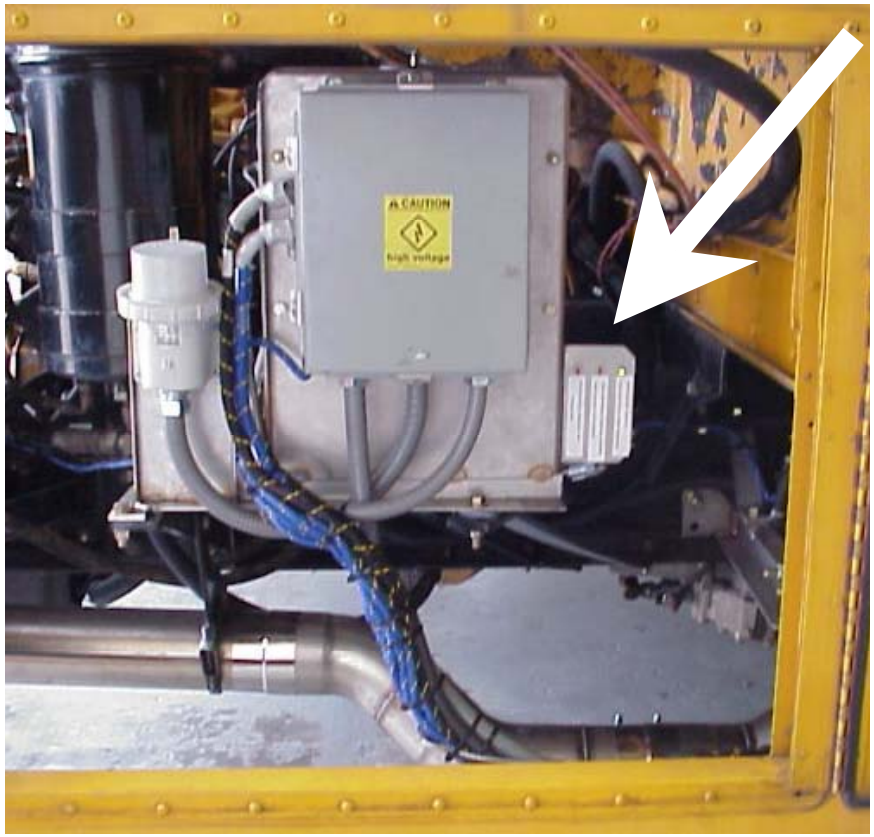
Controls Box

Air Pump Box

Air pump box used on
ICAT demonstration vehicle

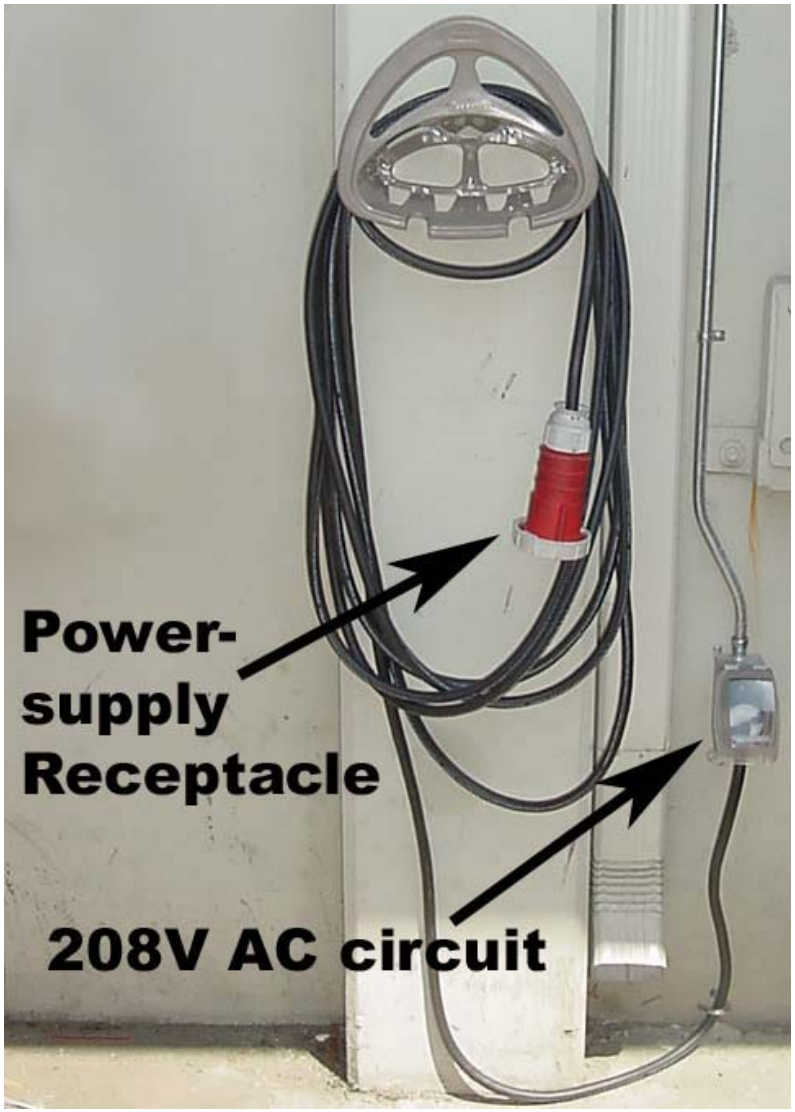
Production version

System Indicator Lights (LEDs)



Location of indicator lights
is customer preference

Power-Supply Station

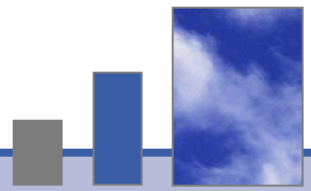


Regeneration Alert and Process

- MLC determines regeneration is needed if:
  - Backpressure is above “B” in. H_2O, for “X” % of the time (all data points since last regen)

    => Histogram
  - Or total operating hours “H” since last regen

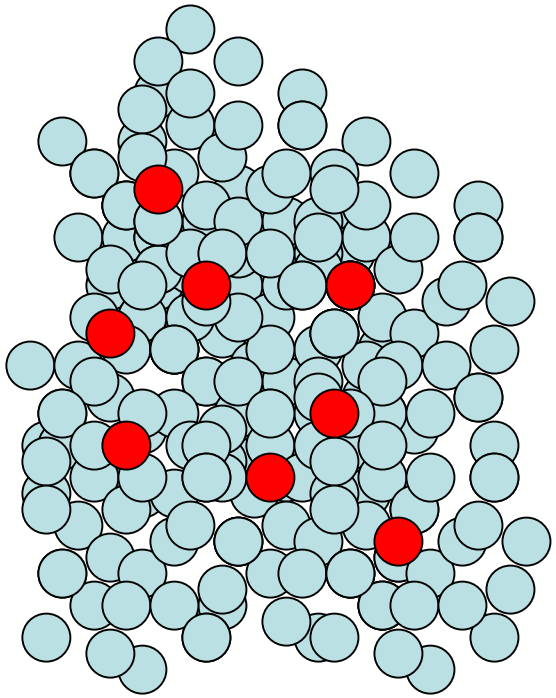
    => Time



Regeneration Alert and Process

Histogram example:

– 21,600 backpressure data points (6 hrs of operation)



< “B”

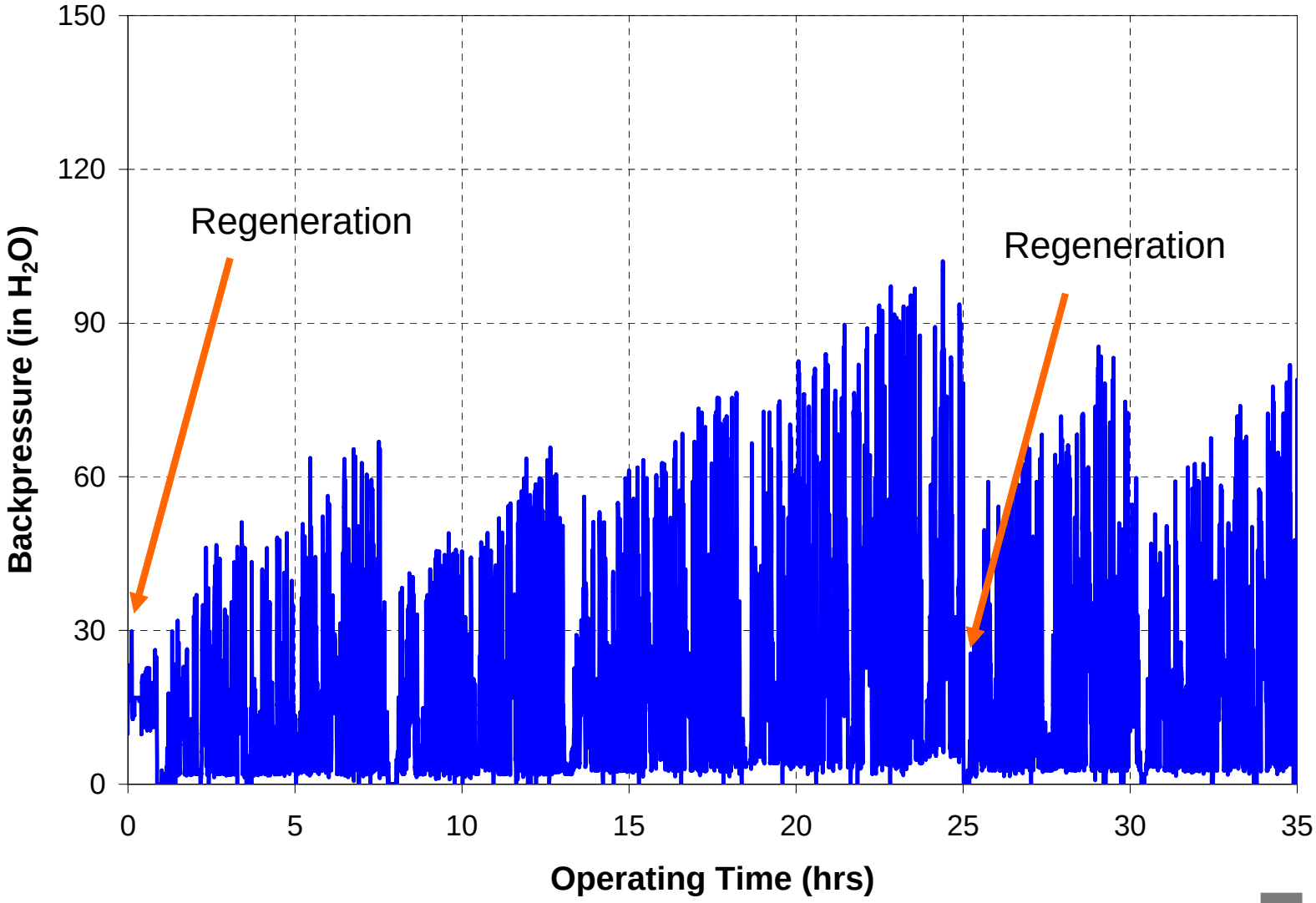
> “B”

Then blinking light is triggered if:

number of ● is greater than

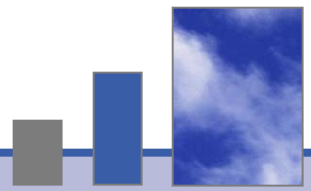
X % of 21,600

Regeneration Example



Regeneration Alert and Process

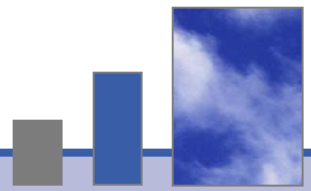
- Regeneration process
  - MLC determines regeneration requested and turns on blinking amber light
  - Operator plugs in unit after shift
  - MLC senses AC and controls heater and air pump
  - MLC turns off amber light after complete regeneration
  - Operator unplugs unit at beginning of next day



Annual Cleaning (de-ash)

ICAT Project Tasks

- Product Testing
  - Extreme durability
  - Regeneration emissions
- Demonstration on school bus
  - Real-world operations
  - Customer behavior
- Emissions Testing of aged system
  - Chassis dynamometer



Extreme Testing

- Operate beyond the point that regeneration is required (factor of 2 to 3)
- Monitor effects on engine and vehicle operations

Class 7 truck (33,000 lb rating)

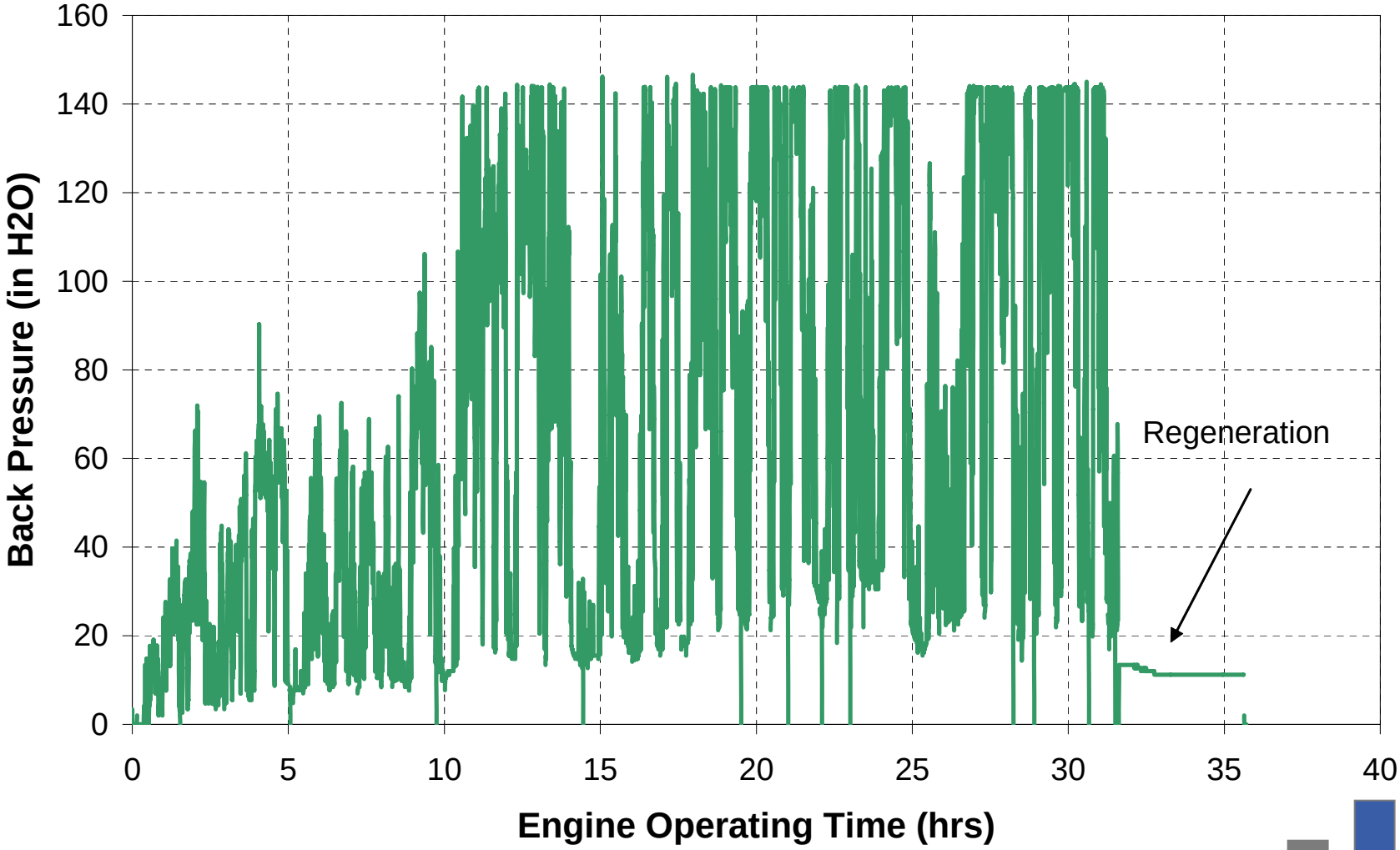
1988 Cummins C engine (250 hp)

0.6 g/bhp-hr PM

Extreme Testing - Backpressure

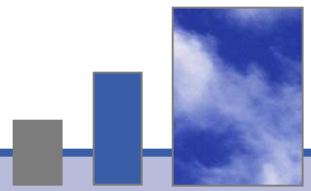
2 weeks between regenerations:

4/24 to 5/8 - 1250 Miles - 339 g of PM



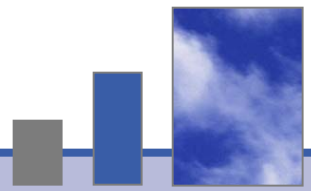
Extreme Testing Results

- Explored extreme loading for SiC
- PM filter canning validated
- Soot load significantly above safe limit for cordierite (20 g/L versus 7 g/L)
- Silicon carbide PM filter maintains integrity
- No drivability impacts noticed
- No engine impacts



Regeneration Emissions (grams)

Test	**PM load**	**THC**	**CO**	**NOx**
1	109	0.00	42	0.03
2	181	0.03	57	0.06



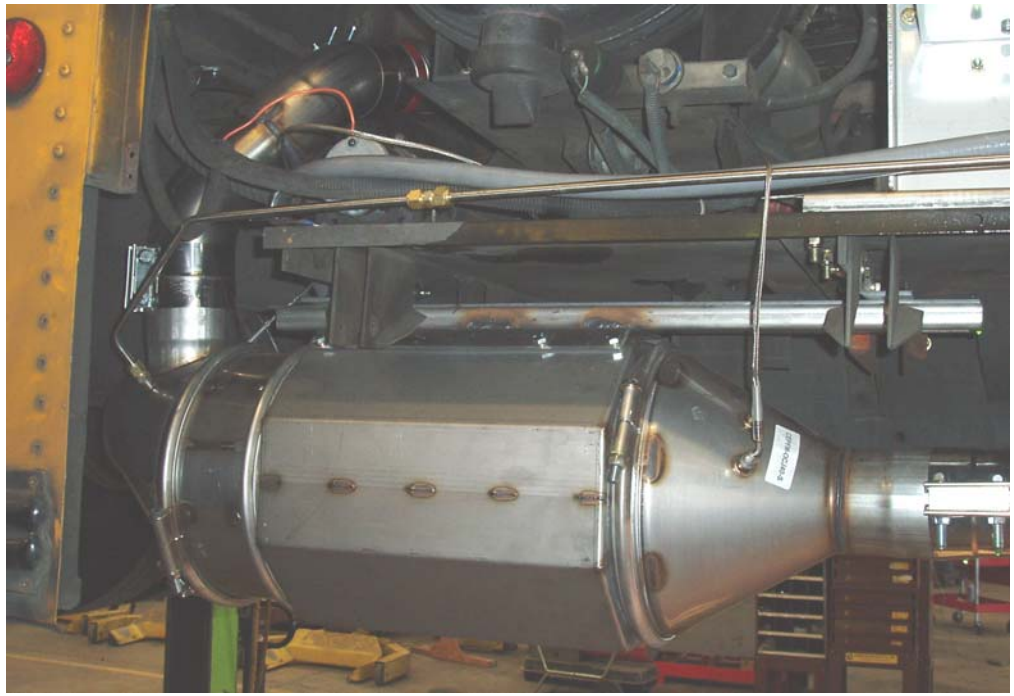
School Bus Demonstration

- Engine
  - 5.9 liter Cummins
  - ISB-EGR
  - (Repowered)
- Evaluate EPF impact on EGR

- Monitor operations
  - Vehicle and Engine
  - EPF
  - Customer behavior
- Typical duty cycle

EPF Installation

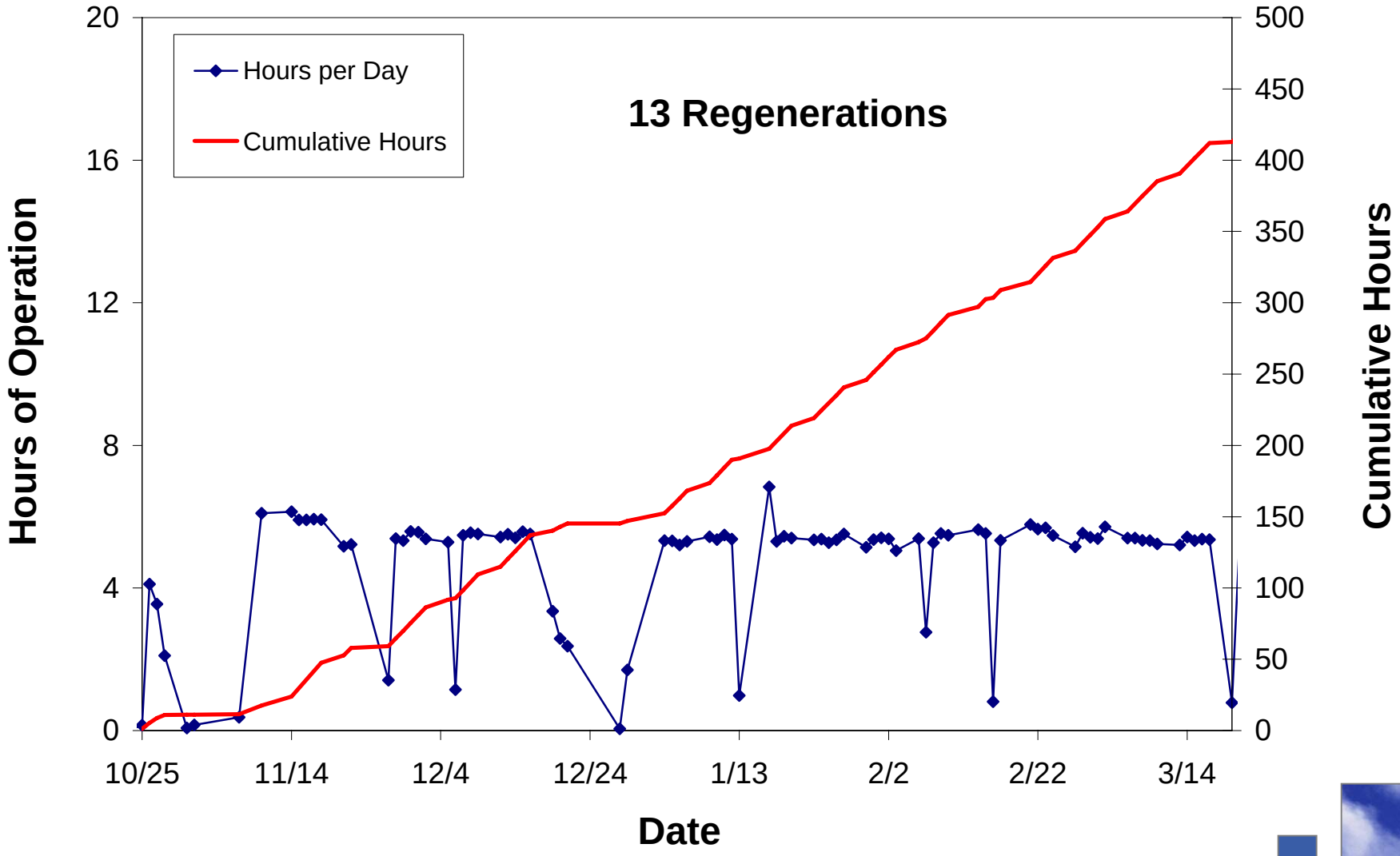
OEM muffler is removed



EPF Installed with Cleaire mounting backbone assembly

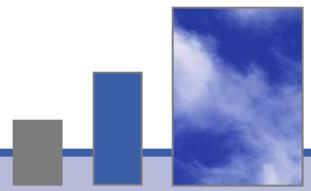
EPF boxes, power plug, & harness

Bus and EPF Operating History

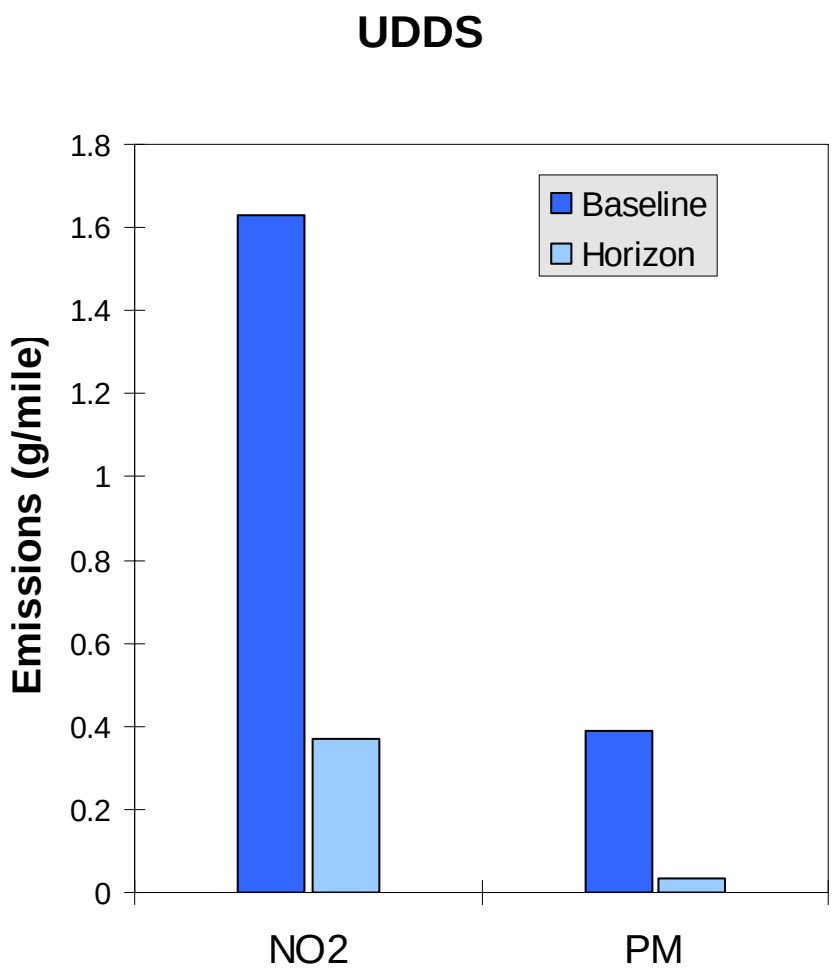


Chassis Dynamometer Testing

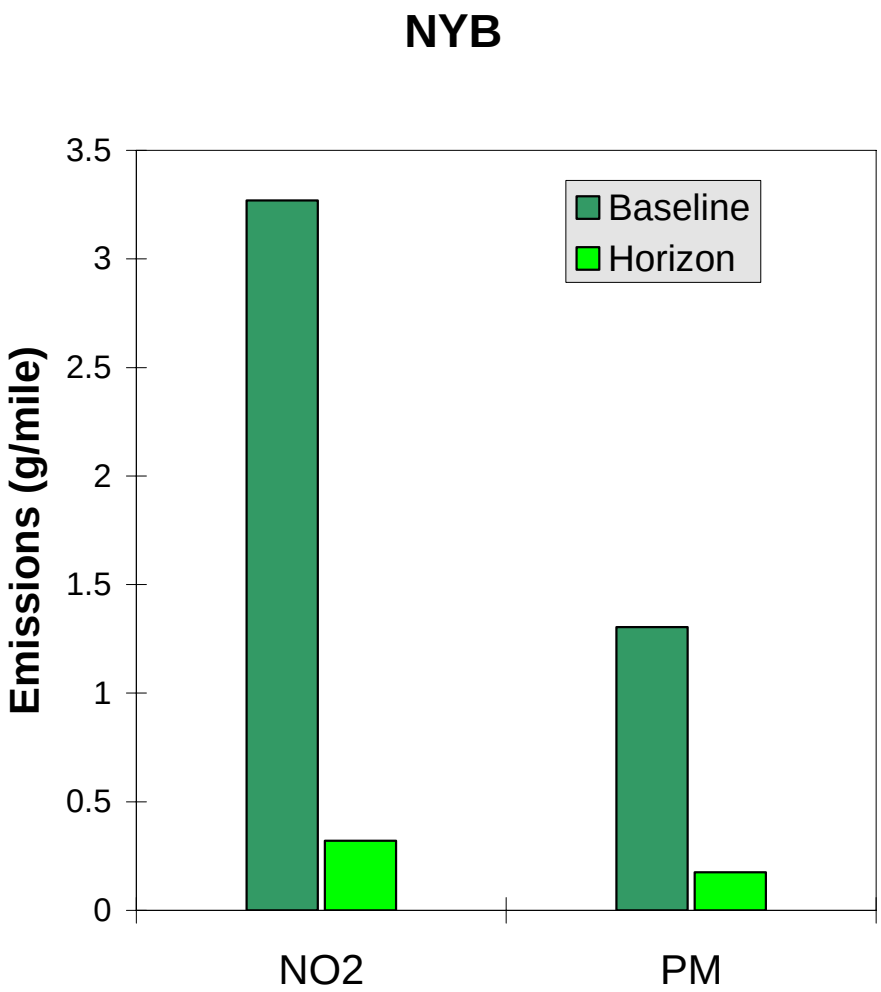
- School-bus-aged PM Filter from Horizon
- Emission performance
- California Truck Testing Services laboratory
- Transient cycles: UDDS and NYB
- ULSD fuel



UDDS Test Results (g/mi)



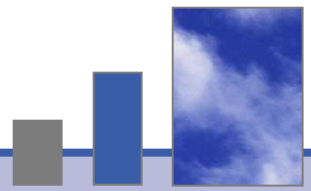
NYB Test Results (g/mi)



Test Results (g/mi)

Cycle	Configuration	NO2	PM
UDDS	Baseline	1.63	0.389
	Horizon	0.37	0.036
	Effect of Device	**-77.1%**	**-90.8%**
NYB	Baseline	3.27	1.304
	Horizon	0.32	0.176
	Effect of Device	**-90.3%**	**-86.5%**

Note: NO_2 mass ~ 3 times PM mass

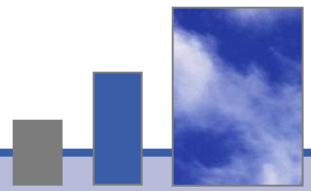


ICAT School Bus Demo – Results

- Horizon performed as designed
- Emission testing (ICAT Task 5)
  - Level 3+ PM reductions
  - Very high reduction of NO_2
- Bus and EGR engine operated normally – no noticeable impact from Horizon
- School District personnel responded as directed to the Horizon's LED indicators
- Elk Grove School District positive about Horizon and installed additional systems

ICAT Project – Lessons Learned

- Field demonstrations successful
  - Extreme field testing
  - Elk Grove school bus
- Level 3+ PM performance
- Very high reduction of NO_2
- Regeneration emissions minor
- Horizon applicable to 0.6 g PM engines
- Regeneration frequency
- Installation infrastructure
- Positive customer acceptance



Questions ?